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Buildings of the Future

Redefining urban living with Building Operating Systems

pwc

Foreword

In the quest for intelligent, highly adaptable, and eco-conscious built environments, the idea of cognitive buildings is transformative. These structures transcend traditional definitions, incorporating advanced technologies to reshape how occupants engage with their living and workspaces.

In our previous report, “Buildings of the future – How to take the cognitive leap”, we examined the concept of cognitive buildings, which use smart technologies to comprehend, analyse and respond to occupants’ needs. Our report revealed important insights into the cognitive evolution and its potential to improve efficiency, comfort, and sustainability – and ultimately transform the overall user experience.

This report explores key aspects of activation, including operational frameworks, decision-making models, the role of technological enablers, and real-world applications. Our analysis examines current examples of cognitive buildings, integrating both established and cutting-edge technologies to envision bold future scenarios. We aim to illustrate the innovative 'future' and 'moonshot' trajectories of cognitive buildings in reshaping the built environment.

Building upon the foundational concepts in our previous report[1], we also navigate through the Building Operating System (BOS) ecosystem, which brings together intelligent technologies and stakeholders contributing to various stages of a building’s life cycle, spanning from initial design to operations and maintenance.

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Introduction

Recent years have seen an unprecedented transformation in how our cities function, driven by rapid urbanisation and the pursuit of sustainable, efficient, and technologically advanced living environments. The Middle East, with its unique blend of tradition and innovation, has become a focal point for pioneering developments in building management systems. As we delve into the trends shaping the future of these systems, we find ourselves at the intersection of technology, sustainability, and human centric design.

The Middle East's journey towards smarter buildings and cities has its challenges. The integration of legacy systems, optimising the edge application interplay, the need for intuitive visualisation layers, and the importance of stakeholder collaboration are all factors that demand our attention. The region, including KSA's brownfield cities and giga projects, has embraced the smart city concept, as evidenced by the integration of cutting-edge technologies into building management systems and the BOS ecosystem.

From the adoption of Internet of Things (IoT) sensors that enable real-time monitoring and data-driven decision making, to the implementation of artificial intelligence (AI) and machine learning (ML) algorithms that optimise energy consumption and enhance occupant comfort, the region is at the forefront of harnessing innovation for the greater good.

BOS plays a pivotal role in achieving sustainable goals. Furthermore, the user experience has taken centre stage. Adaptive components, which learn from the preferences of occupants and adjust conditions accordingly, have emerged, creating spaces that are not just efficient, but also personalised and comfortable.

The evolution of BOS in the Middle East is a testament to the region's commitment to progress and innovation. It is a clear demonstration of the power of technology to transform the very fabric of our urban landscapes, enhancing the quality of life for residents while safeguarding our planet's precious resources.

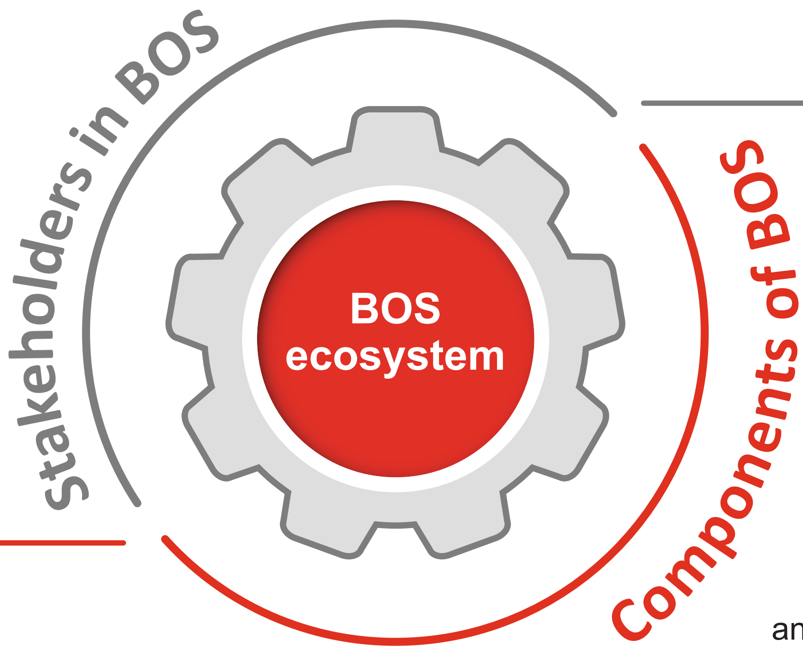
Overview of the BOS ecosystem

In today's rapidly evolving architectural landscape, the concept of smart buildings has transformed the traditional approach to building management and operations. At the heart of this transformation lies the building operating system (BOS), which facilitates the interplay of key components such as devices, applications, and third-party interfaces. The foundational objective is to streamline building operations, optimise energy usage, and enhance occupant comfort and safety, but the BOS is capable of much more. In the BOS ecosystem, multiple stakeholders play pivotal roles:

Overview of the BOS ecosystem

- Regulators
- OEMs
- System Integrators
- Researchers and innovators
- Occupants
- Building owners
- Facility managers

Stakeholders in the BOS ecosystem have different roles including financial, logistical, structural and operational



The components of BOS encompass devices, controllers, and software platforms which orchestrate the building operations

Devices

Sensors, actuators, smart devices, network equipment, data storage and processing devices

Applications - BMS

Automation and control systems with capabilities such as energy, lighting, waste management and others

Third-party interfaces

Exchange of information with external sources

The increasing maturity of BOS enables the transformation from smart to cognitive buildings. The key operational components of the BOS ecosystem work together in synergy to collect real-time data and provide actionable insights.

The case for BOS

Conventional building management uses manual controls and standalone devices to oversee building functions, but these traditional methods have struggled to keep pace with the increasing complexity of building systems. As buildings became more complex, limited scalability became a challenge and inefficiency crept into the management of building operations, while difficulties in optimising energy management and analysing data further highlighted these systems' limitations.

The BOS addresses the limitations of conventional building management systems by offering a more intelligent and integrated ecosystem that enhances building performance and is energy efficient. Achieving the end-state integrated ecosystem, however, requires thorough planning, collaboration among stakeholders, and a commitment to ongoing monitoring and optimisation.

Evolving needs and the limits of conventional systems

01

User preferences

Occupants expect comfortable living conditions, which required the integration of emerging technologies and innovative facilities

Limitations: Occupants may have limited control over environmental conditions such as temperature, lighting, and ventilation in their living space.

02

Interoperability

Seamless vertical and horizontal compatibility between a building's various sensors and systems require an open systems architecture

Limitations: Different systems may operate independently, making it difficult to coordinate and optimise their functions.

03

Energy costs

The desire to better manage energy costs presents an opportunity for data-backed insights and intelligent automation

Limitations: Lights and HVAC systems left running in unoccupied spaces could significantly contribute to increased energy costs.

04

Security

Extra, pre-emptive layers of security are needed to protect against intrusions, data breaches, and cyber attacks

Limitations: Unauthorised access to certain areas may be difficult to detect, reducing the security of the premises.

05

Sustainability

Global and regional guidelines require the reduction of a buildings' carbon footprint or carbon neutrality

Limitations: Sustainable practices are challenging to implement and monitor, leading to excessive resource consumption.

06

Compliance

Changing regulations require regular updates to the existing system

Limitations: A building may struggle to adhere to environmental regulations or safety standards.

The adoption of BOS presents a compelling opportunity to overcome these limitations and provide vendor-neutrality, improved security and compliance with evolving regulations.

The benefits of BOS implementation

BOS implementation promises to evolve the way buildings are operated and managed, offering innovative use cases to meet the ever-changing user demands.

Outcomes	Details	Limitations addressed
Enhanced user experience	Facility managers and building operators monitor and control the building, enabled by a human-centric design **Personalised spaces:** Temperature, air quality, humidity, and lighting are monitored and adjusted for optimal comfort **Intuitive interactions:** Human-machine interactions are customised, context-specific and intelligent **Health & wellness:** User experience-driven health and wellness applications and data-backed insights are made available	User preferences Energy costs
Coordinated building operations	Connected and scalable building operations allow integration of different systems to create a unified end-state, backed by learning **Seamless interplay:** Different devices and systems communicate, with features such as the activation of multiple systems from a single event **Situational awareness:** A single pane of view from a larger perspective allows centralised control and monitoring from a single source	Interoperability
Informed decision making	Advanced techniques analyse large volumes of data generated by building systems **Space optimisation:** A better understanding of efficient use of space for optimal usage **Energy efficiency:** Energy usage is analysed and tracked, identifying inefficiencies and helping to reduce energy costs **Advanced visualisations:** Reports and analytics are generated with data from different systems to optimise building performance **Predictive maintenance:** Sensor data streams are analysed to identify operational anomalies and potential equipment defects, allowing for timely repairs before failures occur	Energy costs Compliance Sustainability Safety
Robust protection	Occupants and assets are safeguarded in both the physical and virtual world **Security and surveillance:** Needs-based access to the building and CCTV feeds is in place **Fire & safety:** The building is monitored for smoke and fire events **Emergency response:** Alerts and guidance are provided in the event of an emergency	Compliance User preferences

BOS changes the landscape of building automation, addressing the limitations of conventional systems.

Accelerators of BOS adoption

The movement towards BOS is gaining momentum, driven by the recognition of the limitations of traditional building management but also by a convergence of trends that include escalating user demand, the development of cognitive cities, rapid technological advancements, and government mandates.

Drivers accelerating the BOS adoption

Increasing urbanisation and smart city initiatives

By 2050, the UN estimates that 70% of the world's population will live in urban areas. Smart city initiatives are gaining traction, notably in US, Singapore, Spain, Saudi Arabia, and are a significant driving force for BOS adoption. Countries like Singapore have also included AI as a core component of their smart city policies.

Growing demand for occupant well-being and productivity

In a high-performance, green-certified building, occupants achieved a 26% higher cognitive score, emphasising the significance of BOS in enhancing productivity and wellbeing. Green building rating systems such as Saudi Arabia's Mostadam, promote application models for integrating BOS within green buildings.

Government-led environmental policy

In the EU, buildings contribute 36% of greenhouse gases, prompting government mandates aimed at enhancing energy efficiency and reducing carbon footprints. For instance, the 2015 Paris Agreement and the US' Federal Sustainability Plan both aim for a reduction in building-related emissions and energy consumption.

Tech-driven cost efficiency

BOS with integrated data analytics can potentially reduce building energy costs by up to 25%. For instance, Dubai Silicon Oasis Authority (DSOA), a smart city regulator, implemented an AI-enabled building management system to save nearly one million AED (0.27 million USD) per month.

In the future we will see even greater innovations in BOS implementation, which is a testament to the continuous pursuit of excellence in the field.

Evolution of BOS: Activation stages

The BOS ecosystem is on a continuous journey of innovation, moving from “foundational” ecosystems that focused on basic automation and control to “future” ecosystems that are characterised by advanced analytics, integration, and optimisation.

The expected destination is a “moonshot” scenario, where fully autonomous and adaptive building management is driven by advancements in technology, changing environmental priorities, and evolving user expectations. This evolution is dictated by a needs-based activation approach and a “build-as-you-go” implementation model.

Evolution of BOS

Foundational

The **foundational** BOS ecosystem is characterised by efforts to control and automate basic building operations such as HVAC, lighting, and security for efficiency and cost savings.

Future

The **future** BOS ecosystem is envisioned for deeper intelligence, integration, and personalisation. It will involve broader aspects of **energy and waste management** as well as **advanced interfaces and integration of third-party apps.**

Moonshot

The **moonshot** BOS ecosystem is an ambitious vision of self-awareness and self-healing, characterised by tech-enabled **hyper personalisation, seamless scalability, and optimisation** to encourage **adaptive, sentient, and greener buildings.**

One Angel Square, Manchester

Co-operative group’s new headquarters is equipped with a comprehensive and socially responsible building management system that includes:

- Data processing to **monitor and control** building systems
- Efficient lighting and insulation
- EV charging points
- **Heat recovery** from IT systems
- 24/7 security and **access control**

Kalasatama Smart City, Helsinki

An experimental brownfield smart city features:

- **An integrated suite of applications** to book shared cars, parking spots, and recreational spaces
- **Autonomous robots** to deliver from shopping malls to homes
- Underground vacuum pipeline for efficient **waste management**
- Digital twin-based analysis of **solar energy potential** and the effect of wind on high-rise buildings

NEOM, Saudi Arabia

NEOM, a visionary city, is set to become a technological test case and will include:

- **Immersive and sentient experience** in the Metaverse with digital twins, XR (extended reality), robotic avatars, and **holographic meetings**
- **Human-centric design** and AI-powered **situational awareness** and insights
- **Adaptive response** by real-time monitoring and risk assessment

Evolution of BOS: From ‘future’ to ‘moonshot’

Buildings worldwide are becoming cognitive structures, and the development of BOS is closely aligning with advancing technologies and the multi-dimensional expansion of services it will offer. The parameters of the BOS ecosystem are continually evolving – the transition from the future to the moonshot stage will positively impact user experience, safety and security, intelligence, scalability, and resilience.

01 User experience

Future capabilities

- **Real-time visual representation** and accessibility of the building environment
- Efficient **AR-based wayfinding**
- **Predictive, personalised settings** for user comfort
- The use of behavioural analytics to **interpret subtle cues and gestures**

Enablers

AR/VR | AI | Behavioral analytics | NLP | Holographic interface | GenAI | Metaverse

Moonshot capabilities

- **Immersive human-building interaction**, improving occupant comfort and well-being
- **Conscious building environment**, for occupant's needs
- Immersive experience through **3D representations** and interfaces
- **Lighting system** mimics natural daylight patterns and the body's natural sleep-wake cycle to improve health and productivity

02 Intelligence

Future capabilities

- **Predictive maintenance** optimises system performance and reduced downtime
- **Real-time data analysis and monitoring** reduces response time
- **Personalised climatisation** maximises comfort by analysing occupancy patterns and preferences
- **Distributed data processing and analysis** using edge devices and federated learning enables faster information handling

Enablers

Predictive analytics | AI/ML | IoT | Digital twin | Edge computing | Federated learning | GenAI

Moonshot capabilities

- **Adaptive architecture** – real time data analysis optimises building configuration for various uses
- **Autonomous decision-making** for building management, resource allocation, and optimisation strategies
- **Context-aware sensor networks** for energy management and **ambient intelligence**
- **Predictive models** forecast energy demand

Future | Moonshot

03 Safety and security

Future capabilities

- Integration of **fire alarm** system with other safety systems such as fire suppression, emergency lighting, and safe evacuation
- Secure data management with **encryption and zero trust security** against cyber espionage
- Integration of the **security system** with facial recognition, thermal cameras, and video surveillance
- **Blockchain-based trust system** assigns scores to devices, ensuring reliability and traceability

Enablers

IoT | Computer vision | Encryption | Digital twin | Blockchain | Active intrusion detection | Nano robotics

Moonshot capabilities

- Integration of **virtual representation and real-time data** on fire incidents to find the exact source and reduce response time
- **Concealed security systems** detect suspicious activity, identify potential threats, prevent crime, and keep occupants safe

04 Scalability and resilience

Future capabilities

- Climate change and natural disaster resilience using **water-inflated property protector and seismic isolation bearings**
- **Standardised** multi-systems for interoperability and future-proofing

Enablers

ML | IoT | Cloud computing | Open API | Nano robotics | Sensor-enabled biomimetic tech

Moonshot capabilities

- **Real-time health monitoring using nano-sensors** to detect structural changes, tensions, and possible damages
- **Modular architecture with adapt-and-play** hardware integration, scaling up or down based on changing building needs

Note: All future technologies and capabilities are also relevant for the moonshot.

Future | Moonshot

Next-gen BOS use cases (1/2)

The use cases for BOS once belonged to science fiction – advancement in technology has made them tangible realities. The integration of AI, ML, digital twin, data analytics, and edge computing have already made a substantial impact and will continue to improve cognitive buildings management.

Use cases	Description	Enablers	Global example
Circadian rhythm-based lighting	• Electric light can enhance human health by synchronising with circadian rhythms. This involves adjusting intensity, colour, and correlated colour temperature to mimic natural daytime and nighttime signals.	• Intensity and color tuning • Stimulus tuning	**SAGA Space Architects, Denmark:** A Denmark startup is testing a circadian light panel designed to improve sleep by learning from space-tested data. There are specific building regulations to meet the requirement for good circadian rhythm alignment in the country.
Sensor-based structural integrity monitoring and healing	• Contemporary structures incorporate biomimetic design principles, mirroring nature's processes (such as regeneration) and informed by data from digital sensors fitted in the building.	• Sensor-enabled biomimetic tech	**Mimicrete, Cambridge, UK:** A UK startup is working on a self-healing concrete solution that will automatically repair cracks when they occur. Maintenance work can be seamless and near silent if integrated with sensors.
AI-driven comfort control	• An integrated AI comfort control system ensures a seamless experience using predictive climate control that analyses historical data, weather forecasts, and real-time sensor information. • A smart parking system directs the driver to a specified parking spot by recognising the car.	• AI • Robotic technology • Predictive analytics	• **The Edge, Amsterdam, Netherlands:** A smartphone app synchronises with the occupant's schedules and assigns a workplace accordingly. It knows the occupant's preferences and automatically sets the lighting and temperature. • **The BEEAH Headquarters, UAE:** Leverages AI-based solutions to adjust light and temperature based on individual preferences.

Future Moonshot

Next-gen BOS use cases (2/2)

Use cases	Description	Enablers	Global example
Simulation-powered energy optimisation	• Digital twin analyses data from building sensors, adjusting settings in real-time to decrease energy consumption and lower operational costs significantly. • It can also be used for predictive maintenance to detect failures and reduce downtime, which enhances energy efficiency through well-maintained equipment.	• Digital twin • Data analytics	• **The Shard, London, UK:** Digital twin uses real-time data analysis to allow facility managers optimise energy consumption and reduce waste, control the HVAC system for occupant comfort, and manage maintenance of different building systems. • **Smart Housing Projects, UAE:** Uses digital twins technology for energy efficiency, security systems, and carbon footprint reduction, contributing to a more sustainable future.
Invisible security enhanced protection	• Implementing invisible security in a building involves discreetly placing surveillance cameras and motion sensors, strategically hidden within everyday objects. • These covert measures, integrated with smart analytics and access control systems, enable unobtrusive monitoring and swift response to potential security threats.	• Computer vision • Anomaly detection • Deep learning	**National Museum of Singapore:** The Museum implemented an invisible security system to secure and safeguard cultural treasures.
Advanced-analytics based centralised visualisation	• A centralised dashboard system processes large amounts of data and monitors building operations such as energy usage, utility replacement, and generates alarms.	• Data analytics • Digital twin	**FIFA World Cup Stadium, Doha, Qatar:** A unified command centre, Aspire Command and Control Centre, allows real-time monitoring and control of all eight stadiums from a single location using digital twin technology.

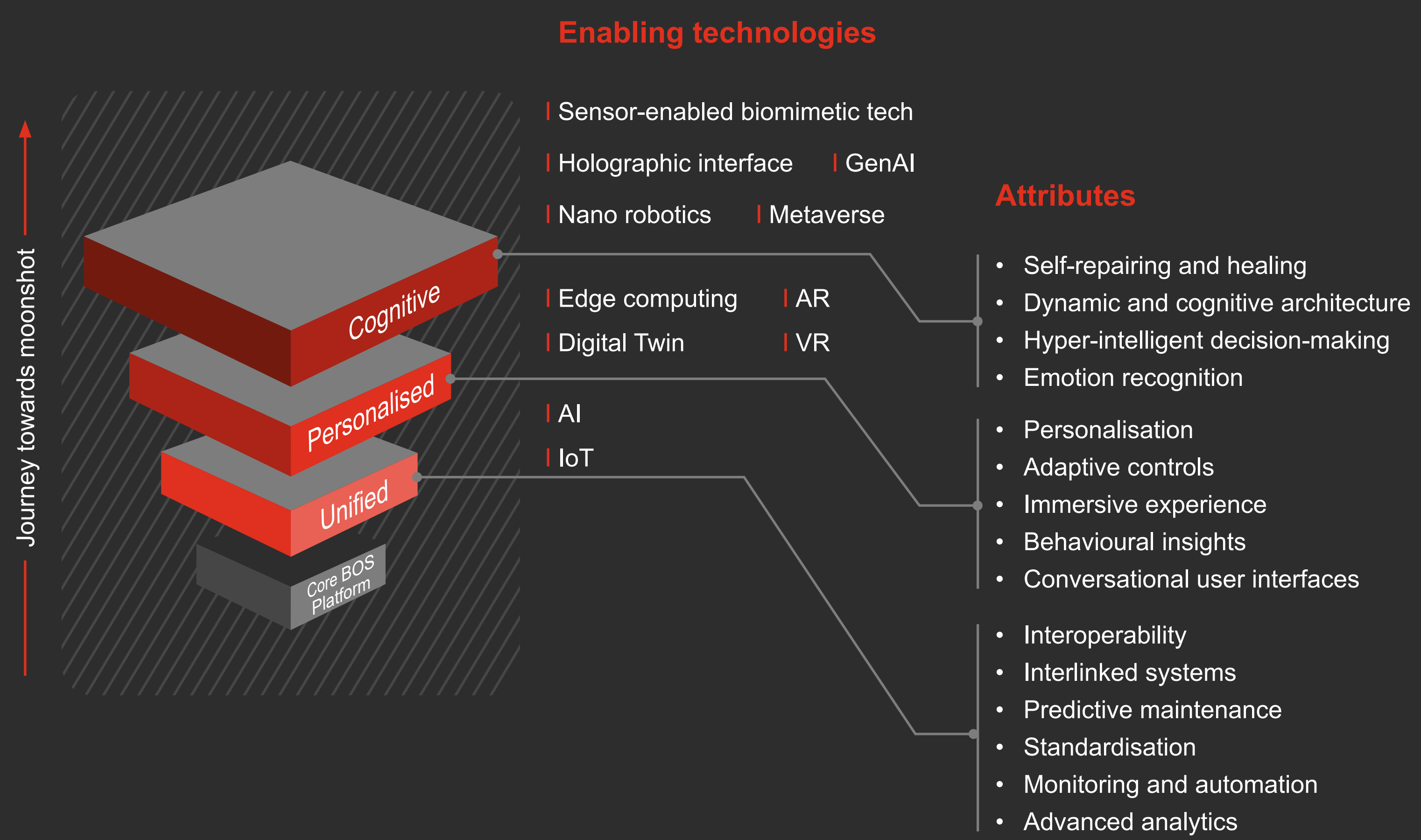
Future Moonshot

Activation framework

If BOS is to reach the moonshot stage, its capabilities (and therefore transformative potential) will need to be enhanced across three distinct layers:

- The **Unified layer** establishes interoperability and standardisation in the building environment, laying the groundwork for centralised monitoring and automation, and seamless communication between building systems.
- The **Personalised layer** introduces customisation and adaptability, enabling tailored experiences for occupants.
- The **Cognitive layer** represents the leap into disruptive innovation with dynamic architecture and self repairing capabilities.

Increased functionality, personalisation, and ambition at each level will allow stakeholders to build upon foundational technologies and ultimately achieve disruptive innovation that redefines the future of buildings and urban environments.

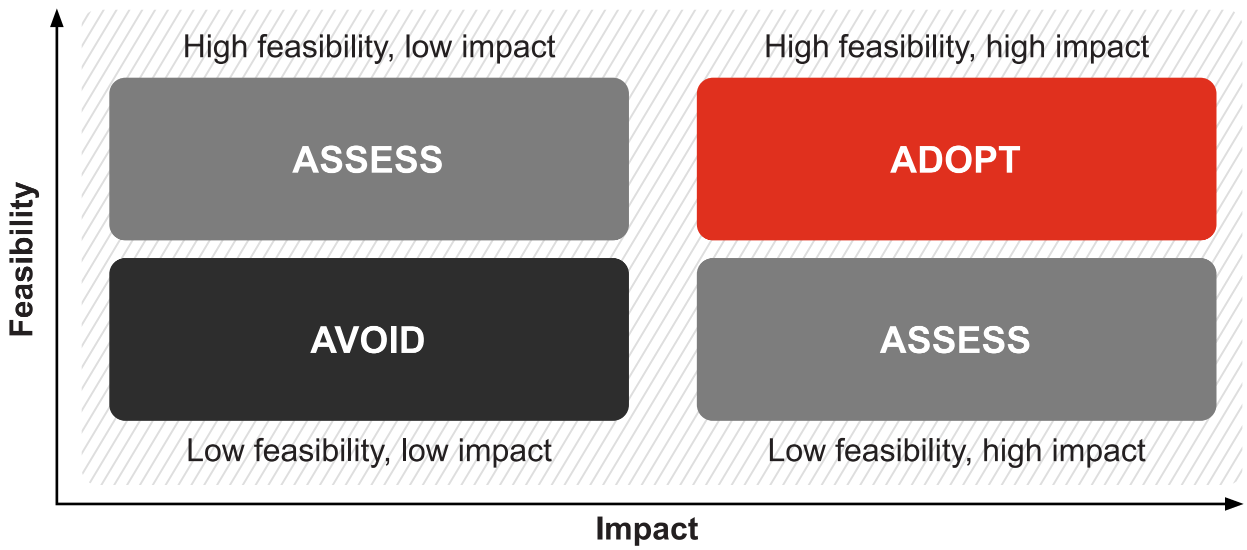


The layers represent a progression towards more advanced BOS. The cognitive layer builds on attributes and capabilities from the unified and personalised layers to create buildings with dynamic and responsive environment that enhance occupant lives.

Activation framework: Decision towards moonshot

In the urban built environment, success depends heavily on the process of categorising transition options. This means a comprehensive analysis of both feasibility and impact. In transitioning toward the moonshot stage, different structures (whether a building, community, or a megaproject) will have different levels of feasibility and impact as illustrated in the 3A framework. These are based on factors, such as budget, infrastructure readiness, technical maturity, and ROI, influencing their likelihood of success and long-term viability in the transition.

3A Framework: Decision based on feasibility and impact



Buildings

A standalone structure that functions independently and serves various purposes for human occupancy.

Its smaller scale, lower budget, limited technical maturity and lower interoperability needs makes it reaching the moonshot stage less justified. Moreover, its economic, social and environmental impact is also limited due to its limited scale of implementation and usage.

Community

A group of connected buildings or structures with shared interests and goals, such as neighbourhoods, campuses, and societies.

Its moderate scale strikes a balance between potential benefits in energy efficiency, community engagement and sustainability with challenges related to scalability, integration and funding. This makes a case for exploring the possibility of reaching a moonshot scenario.

Mega project

A large-scale project with extensive infrastructure, comprising multiple buildings and elements like smart highways or airports.

Its high profile and scale, integrated nature and dedicated budget makes it ideal to transition to moonshot stage. This allows incorporation of technology, large-scale implementation, and collaboration with diverse stakeholders, maximising impact, operational efficiency, and progress towards sustainability.

Activation framework: Key considerations

As entities navigate the ever-changing landscape of smart buildings, they must conscientiously consider numerous factors to ensure both adaptability and longevity and the smooth integration of new technologies. This journey involves cost planning, considering integration choices, training, maintenance, compliance, and sustainability aspects. These are crucial considerations that forward-thinking entities must keep in mind as they strive for a resilient and future-proof foundation for intelligent building operations, aiming for sustainability and long-term effectiveness.

Cost and planning

- **Needs assessment:** Comprehensive assessment of the building's needs, considering factors such as size, occupancy patterns, and technology maturity of existing systems.
- **Cost analysis:** Determine the budget allocation with cost estimates, including expenses for continuous maintenance, training costs, and potential ROI calculations to justify investments and ensure cost-effective delivery of desired outcomes.
- **Stakeholder buy-in:** Presenting clear ROI, showcasing regulatory compliance, and emphasising data-driven insights can foster a positive environment and secure stakeholder support for moonshot BOS.

Infrastructure and interoperability

- **Compatibility and interoperability:** Ensure compatibility among building systems, stakeholders, and project components and interoperability of various devices, protocols, and technologies for seamless operations and a cohesive and functional environment.
- **Future proofing:** Anticipating technological advancements and planning for system upgrades to avoid obsolescence and maintain the building's competitive edge.
- **Implementation complexity:** The complexity of implementing a moonshot BOS may be dependent on multiple factors such as building size, number of systems to be integrated, communication protocols, level of customisation, sensors' density and legacy systems in place that require integration.

Training and maintenance

- **User awareness and training:** Provide training to building occupants and staff so they can effectively use and interact with the systems and devices deployed in the building, community or campus.
- **Performance monitoring and optimisation:** Establish protocols for monitoring, feedback mechanisms, and evaluation frameworks to track performance and stakeholder satisfaction.
- **Maintenance and support:** Incorporate maintenance schedules, periodic checks on operational parameters such as energy efficiency, operational efficiency, cost savings and system uptime, ensuring continuous learning and improvement.

Compliance and sustainability

- **Sustainability:** Incorporate sustainability initiatives centred around planning strategies such as green infrastructure and collaborative partnerships to optimise resource usage and improve resilience.
- **Standardisation of data protocols:** Standardisation is essential for seamless communication between various building devices and systems. By choosing open and widely accepted protocols such as BACnet or Modbus, interoperability, scalability and efficient data exchange is ensured.
- **Compliance:** Understand and adhere to local building codes, standards, and regulations for building operations, data privacy, and energy efficiency to prevent potential complications.

Opportunities in Middle East

Countries in the region are undergoing a visionary transformation and setting ambitious goals. Giga and mega projects are underway, with the goal of improving quality of life and promoting sustainable development.

These multibillion-dollar initiatives drive a growing demand for advanced infrastructure and technology, particularly in smart buildings, and presents a foundation for futuristic BOS, leveraging AI-powered demand forecasting and automation. The region is also seeing greater demand for high-end buildings with premium amenities, while government regulations are simultaneously motivating developers and building owners to adopt futuristic systems. The unique combination of governmental support, market demand, and technological expertise is poised to generate more sustainable and efficient environments for the future.

Factors fueling the demand for BOS

Saudi Arabia's (National Transformation Program) NTP is a part of the Saudi vision 2030 program, which aims to accelerate digital transformation and sustainable development in smart cities.

Tech advancements driving increased adoption and integration

Building automation is on the rise due to technological advancements. Integrated into BOS, features such as voice control modulation and remote event monitoring enhance the consumer experience. The integration of AI and data analytics further boosts the market's long-term prospects. BOS is a crucial element of the smart building ecosystem and is witnessing the emergence of innovative technologies such as Building Information Modelling and IoT.

Qatar National Convention Centre was accredited for its approach to environmental stress mitigation and has achieved high sustainability ratings under the GSAS certification system

Increasing focus on energy-efficient buildings

Commercial buildings in the Middle East exhibit significantly higher energy consumption than other regions, primarily due to extreme heat, heavy dependence on air conditioning, and widespread use of glass exteriors. To address this issue, the building industry is increasingly adopting eco-friendly architecture and sustainable construction practises, leading to an increase in demand for BOS.

Emirates such as Sharjah, Abu Dhabi, and Dubai have specific green building regulations that align with UAE mandates for construction projects

Government regulations and initiatives

Middle Eastern governments are actively promoting smart buildings, with substantial investments in R&D, technology, and integration of smart city projects. Regulations have been introduced to foster sustainability, emphasising the necessity for advanced building management systems and comprehensive BOS to ensure compliance and enhance building performance.

Way forward

The building management and automation field has seen significant advancements, enhancing user experience, simplifying operations, and fostering sustainable living environments. At the heart of this change is the Building Operating System, powered by technologies, such as AI, IoT, edge computing, NLP, and predictive analytics. As these technologies continue to evolve, more improvements and innovations will follow.

The evolution of BOS begins with basic automation and control and progresses, progressing toward advanced analytics, integration and optimisation in the ‘future’ phase. The ambitious ‘moonshot’ phase envisions fully automatic and intelligent operations and promises highly intuitive interfaces and unparalleled experiences.

We are already witnessing glimpses of BOS’s futuristic potential. Assessing the feasibility and viability of advancing buildings, communities, and mega projects to the moonshot stage suggests that mega projects are the most suitable, give their budget capacity, ROI potential, infrastructure readiness, and technical maturity.

With recent forward-looking government initiatives, the Middle East is on the brink of a significant economic and social transformation. Smart, cognitive, and sustainable buildings are set to play a major role in this shift, paving the way for broader adoption of futuristic building operation systems.

Looking ahead, it is evident that a future-ready BOS represents not just an evolutionary step, but a transformative leap forward in building operations.

References

01. https://www.pwc.com/m1/en/publications/documents/buildings-of-the-future-how-to-take-the-cognitive-leap.pdf

02. https://assets.new.siemens.com/siemens/assets/api/uuid:7a50d26e-4d21-40ac-96df-e2c837cfb31d/sfs-uk-bt-cost-of-not-investingv4.pdf

03. https://commission.europa.eu/news/focus-energy-efficiency-buildings-2020-02-17_en

04. https://www.sciencedirect.com/science/article/pii/S0360132316304723

05. https://unstats.un.org/sdgs/report/2023/goal-11/

06. https://www.telecomreview.com/articles/exclusive-interviews/6087-neom-in-cybersecurity-strong-preparation-and-continuous-evolution

07. https://bregroup.com/case-studies/breeam-in-use/one-angel-square-reflects-a-growing-awareness-that-sustainability-pays-co-operative-group-hq/

08. https://www.inferrix.com/index.php/category/building-management-system/

09. https://fiksukalasatama.fi/en/building-blocks/project-portfolio/

10. https://commercialisation.esa.int/2023/07/sagas-circadian-light-revolutionising-astronauts-sleep-in-space/

11. https://www.mimicrete.com/

12. https://www.bloomberg.com/features/2015-the-edge-the-worlds-greenest-building/

13. https://foundtech.me/digital-twins-in-architecture-and-construction-streamlining-the-building-lifecycle/?lang=en

14. https://www.prnewswire.com/news-releases/johnson-controls-honors-intaleq-with-openblue-pioneers-award-for-first-of-its-kind-stadium-technology-at-world-cup-qatar-2022-301663725.html

15. https://www.boschbuildingsolutions.com/xc/en/news-and-stories/security-for-unique-cultural-treasures/

16. https://constructive-voices.com/qatar-top-green-buildings/

17. https://mep.gov.sa/en/Pages/NationalTransformationProgram.aspx

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